

Interaction Design Studio Learning in Virtual Worlds

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Abstract. The paper suggests that Virtual Worlds (VWs) have many unique advantages for supporting interaction design studio activities, provided that they are designed to include appropriate workplaces and interactive tools to foster collaboration and creativity. We present an approach for employing VWs that proposes the use of prospective tools and workplaces throughout the following key activities of interaction design studio courses: design brief, design thinking, design practice (conceptual and detailed), the desk crit, design review and user evaluation. Then, we describe a blended interaction design studio course on the basis of this approach, that ran through a whole semester. We found that the VW design studio is an engaging and constructive experience for students: in the VW environment students and tutors held many online meetings, and students constructed several models about their design project, they developed a digital prototype and conducted a remote usability evaluation. In addition the persistence of the environment and the developed VW tools helped students and tutors to achieve careful feedback and reflection during the design project lifetime. Nevertheless, a number of challenges remain for wider implementation: the refinement of the instructional design approach, the usability of VW tools, further integration of VWs to professional design tools, and the conduction of other full-scale VW design studio courses.

Keywords: Virtual World; Design Studio; Interaction Design; Learning

1. Introduction

The design studio has a long tradition as the principal approach of design learning that can be traced back to the tutoring practices at the Ecole des Beaux-Arts (i.e. School of Fine Arts, France, 1819-1914) and the Bauhaus (Germany, 1919-1932). The design studio is widely conceived as both (Broadfoot and Bennet 2003) the *physical place* where designing occurs and/or the *learning process* of designing that incorporates ‘learning by doing’ and ‘reflection-in-action’ (Schön 1987). The design studio place contains spaces, tools and materials for design, arranged

informally according to the designers' convenience. Learning in the design studio emphasizes simple but powerful creative thinking methods that boost creativity, as well as sketching, low-fidelity prototyping and modeling to help idea expression and exchange.

The design studio is adopted as a teaching approach for interaction design (e.g. Greenberg 2009; Blevins 2010; Hundhausen et al. 2010), which is quite new as a design discipline compared to architecture or product design. However, it is rapidly evolving as "*the practice of designing interactive digital products, environments, systems, and services*" (Cooper et al. 2007). The outcome of interaction design is a digital artifact of some sort, which is constructed by quite different materials and mediated by quite different tools, in comparison to other design disciplines. In interaction design there is clearly a number of intangible qualities that affect the design of the digital artifact, like for example services, software and user experiences, which are interleaved with the tangible aspects (Lowgren and Stolterman 2004). Therefore, teaching and learning interaction design in a design studio has to address several shortcomings of the traditional approach, including:

- In a traditional design studio, students produce paper prototypes and rough mockups. It is hard to demonstrate and evaluate the functionality and interaction qualities of digital artifacts as well as to present and simulate usage scenarios in realistic contexts that are required for interaction design.
- The collaboration of student groups in the traditional design studio is constrained by space and time arrangements.
- Tutors in a traditional design studio need to devote a large amount of time with each student or group to track down their progress. It is hard to be aware of individual student effort for each group work.
- It is difficult for tutors to collaborate remotely with groups. Thus, support is limited to course hours.

These shortcomings highlight the need for platforms that support studio-based learning online to allow for time flexibility, compensate for geographic constraints and support simulation and computational activities that are difficult to conduct in the traditional environment.

Virtual Worlds (VWs) combine a number of characteristics that may be valuable for addressing the identified issues. Concepts and ideas can be visualized and manipulated in real-time, users can meet and collaborate in shared workplaces, there is an increased awareness of the work in progress and of user activities, the designed product or system can be presented in a realistic context and evaluated by team members or external users, and some functional aspects can be included in the prototype, e.g. moving or rotating parts, inter-object communication, point-and-click user interaction, etc. Additionally, VWs have become nowadays more robust and widely accessible compared to earlier approaches in the past decades, especially due to the constant increase in graphics cards performance and network bandwidth. Second Life, which is today's most popular general-purpose VW, is already being used extensively for educational (De Lucia et al. 2009) and collaborative design (Chase 2008) purposes. However, in the majority of the educational uses of Second Life, traditional classroom activities are simply reproduced in the VW, without taking full advantage of its simulation and real-time interaction affordances. Furthermore, collaborative design approaches using Second Life mostly focus on co-construction of designed spaces leaving out other important phases and activities of the design process.

VWs are general-purpose platforms that provide several affordances and an infrastructure that can enable the creation of digital places for learning and design. This certainly requires not only a re-creation of the physical environment but includes the orchestration of specific activities in the VW, the design of workplaces and tools that mediate these particular learning and design activities in the VW and the pragmatic and full-time application of these in respective courses. The paper identifies an approach for using VWs for the support of teaching and learning at an interaction design studio and presents its application at a blended postgraduate course that ran through a whole semester. The proposed approach identifies prospective VW workspaces and tools for typical phases of the design studio like: the design brief, design thinking, design practice (conceptual and detailed), the desk crit, design review and user evaluation. The blended studio made use of the VW in every session following the proposed approach: in the VW environment students and tutors held many online meetings, and students constructed several models about their design project, they developed a digital prototype and conducted a remote usability evaluation. We found that the VW

design studio is an engaging and constructive experience for students, however a number of challenges remain for wider implementation.

2. Uses of Virtual Worlds Related to Design

Education

VWs have already been successfully employed as educational environments in various disciplines. An extensive review on the uses of VWs for learning can be found in Hew and Cheung (2010). Nowadays, the popular world of Second Life is being used by schools and universities as a complementary educational place in which the learning community can meet and collaborate. This is not surprising, as VWs have a number of affordances for learning. According to Dalgarno and Lee (2010) the use of educational VWs can lead to enhanced spatial knowledge representation, experiential learning in simulated environments, learners' intrinsic motivation and engagement, and to improved transfer of knowledge and skills to real situations. Additionally, a number of researchers (Dede 1995; Girvan and Savage 2010) claim that VWs are an ideal medium for constructivist learning activities, in which learners can actively gain knowledge through collaborative experimentation.

A further key characteristic of VWs which is essential for supporting the interaction design process is their successful use as collaborative mediums. Avatar-based representations, synchronous and asynchronous means of collaboration and enhanced social and workspace awareness are some of their features that can be exploited by collaborating communities. A number of Collaborative Virtual Environments (Benford et al. 2001) using various technologies and in various disciplines have been proposed in the last decade, some of which are specifically built to support design tasks (Ragusa and Bochenek 2001). However, the high cost of immersive VR hardware and the lack of adaptability and extensibility of application-specific solutions raised the need for more generic and widely accessible platforms for collaboration in 3D. Nowadays the use of general-purpose VWs, such as Second Life, ActiveWorlds or OpenSimulator has emerged as a more preferable solution to design collaboration.

The concept of using VWs for collaborative design has been proposed by Maher et al. (1999). They describe 'virtual studios' as VW models that create a

sense of place and are presented like physical design studios. These places may include tools that designers are familiar with and allow them to perform appropriate design activities. The authors further present the approach of “designing within the design”, i.e. the design studio being the model of the product or place being designed. This approach has the advantages that designers use a single integrated environment for both private and collaborative activities, that they may visually explore the design while being designed and that they may get immediate feedback from their actions leading to further reflection.

The affordances of VWs as a tool for collaborative design have been further explored by numerous researchers. Ehsani and Chase (2009) present four architectural collaboration projects in Second Life and propose various collaboration modes depending on the level of user participation and on the governance model. In another study, Koutsabasis et al. (2012) discuss the value of VWs for collaborative design based on the results of three case studies in architectural, interior space and user interface design. The results indicate that VWs can effectively support conceptual design activities and can also be employed for review and customer-centered evaluation of conceptual design.

There are also a number of studies that explore the use of VWs in specific activities of the design process such as scenario-based design, prototyping and evaluation. Bardzell et al. (2006) propose the use of machinima for presenting and evaluating use case scenarios of designed products. Machinima is a technique for simple and fast video production by recording the activity within VWs, which is quite popular nowadays. It can be used in an interaction design studio as a method of scenario-based design alternative to storyboarding in paper. It can be easily performed if the concept is already present in some visual form in the world, it does not require sketching skills, and the results may have better quality.

Kim et al. (2008) claim that Second Life can be used for immersive prototyping to receive feedback on new ideas and for immersive event simulation to study people’s reactions in real-world events. Sun and Gramoll (2004) present a VW that visualizes the results of a structuring simulation in real-time and has been used for engineering education. Similarly, a VW has been used for the visualization and evaluation of user interfaces as part of a user interface design model (Vanderdonckt et al. 2004). Finally, VWs have been used as a simulation framework to test and evaluate sensor-based systems (Prendinger et al. 2009). The

ability to construct and test functional prototypes is a critical requirement of interaction design studios, as the focus of interaction design is not only on the structure and interface of the designed system, but also on the user experience of interacting with it. Given their ability to display functional prototypes placed in realistic concepts, VWs have been applied for user evaluations as well. Second Life has been used as a platform for presenting innovative products and services to the user community and for receiving comments and feedback (Kohler et al. 2009).

There are already a few paradigms in which VWs have been used for design education. The system presented by Bowman (1998) is an immersive environment for designing an animal habitat. Students can modify features such as terrain, visitor viewpoints, visual elements, etc. while being immersed in the environment. It is intended to help inexperienced students apply the theories they learned in a realistic problem context. Unfortunately, approaches based on immersive VR systems failed to reach wide audiences due to their high cost and to usability and health problems related to the respective hardware. It took almost a decade after Bowman's system until Desktop VR solutions were mature enough to be used in formal educational settings. Gul et al. (2009) present a study of design learning in VWs through a collaborative design project that has been set up between two remote student communities using Active Worlds platform. The project involved the design of a two virtual places (a home page and a 3D place in the VW) using a shared whiteboard and the VW.

The above mentioned studies focused on specific aspects of educational, collaborative and design activities in VWs that were explicitly or implicitly related to interaction design education. However, there is still a lack of paradigms of long-term use of VWs as an educational platform to support all (or at least most of) the student activities found in design studio courses. The focus of our work is to propose such an integrated approach for using VWs as a learning platform for interaction design studio courses.

3. Enhancing Interaction Design Studio Activities with Virtual Worlds

Learning in the design studio incorporates a number of unique activities that have been extensively discussed in related bibliography: the design brief, the desk crit,

the interplay of design thinking and practice and the design review. The design brief signifies the beginning of the design process and it is often a short but solid description of the design project or problem after communication with the client (Ryd 2004). The 'desk crit' (Schon 1987) describes the interaction between the tutor and the student in a timely context about student design work in the design studio. Design thinking refers to the processes of thoughtful idea generation and exchange and includes various methods for organizing personal or group work (Cross et al. 1996). Design practice refers to the acts of putting the design into form and function with various materials ranging from paper and pencil to CAD (Computer-Aided Design) and prototyping systems. The design review (or jury) refers to the scrutinizing of student work by the tutor (or sometimes other students as well) (Shaffer 2003) and in the case of interaction design also includes user-centred evaluation of the designed artifact on various aspects of the user experience (Tullis and Albert 2008).

Virtual world design studios may complement the aforementioned traditional studio learning activities in a number of ways. First, they can minimize geographic and time constraints by allowing remote design participants to meet in the digital studio and progress on collaborative design work, synchronously and/or asynchronously. Second, VWs may provide enhancements to some of the traditional design studio methods and tools in order to allow design participants to reach to design proposals more effectively. Last but not least, VWs can be employed in the context of new methods and tools that mediate design processes and that can be proposed to perform design activity. In this section, we discuss the ways by which the Virtual World Design Studio can enhance the aforementioned characteristics of the interaction design course; an outline of these prospective activities, tools and workplaces are also depicted in Table 1.

Table 1: Overview of prospective activities, methods, tools and workplaces of a Virtual World Design Studio.

Traditional Design Studio Activities	Related Methods for Interaction Design	VR design studio activities	Prospective VR Tools and Workplaces
Design brief Presentation of problem space / problems; creation of a compact description of design project;	Interviews with tutor or client (if available); brief research on competitive products and technology; feasibility assessment	Presentation of design brief Discussion and documentation of key guidelines and requirements Exhibition of design brief	<u>Tools:</u> Projector; design brief templates <u>Workplaces:</u> meeting place
Design research Documentation of end-user requirements, the context and place of application and technology	Interviews; focus groups, observation; contextual inquiry; work flow models; task analysis; content inventory; competitive analysis; bibliographic research; study of documentation; questionnaires	Documentation of design research findings Knowledge modeling (e.g. personas) Discussion and refinement of models Exhibition of key findings	<u>Tools:</u> Projector; resource lists; white boards; notebooks; <u>Workplaces:</u> personal workplace; group workplace
Design thinking Exploration of design space, ideas and metaphors; identification and analysis of design options;	Brainstorming; scenario-based design methods; interpretation sessions	Remote design thinking in groups Documentation of main ideas and metaphors Annotations with comments (asynchronous)	<u>Tools:</u> Projector; whiteboards; personal notebooks; templates for documenting decisions. <u>Workplaces:</u> Group workplace
Design practice <i>Conceptual design:</i> Putting ideas into abstract form and function; making sense of priorities; mock-ups. <i>Detailed design:</i> 3D modeling & prototyping according to specifications and guidelines	Conceptual design: Sketching; mood boards; personas; scenarios; storyboards; concept models; flow charts; concept models; vision Detailed design: wireframes, screen designs, paper and video prototypes, online (web) prototypes	Atomic and group construction of concepts and prototypes Discussion on the conformance with requirements, guidelines and specifications Prototyping of 3D objects and user interfaces Simulation of designed artifacts application and behaviour	<u>Tools:</u> Specific tools for design & modeling in the VW like: sketch boards, 2D design tools, virtual prototyping. <u>Workplaces:</u> personal workplace, group workplace, prototyping workplace
Desk crit Intense and loosely structured interaction between tutor and student; presentation of student work;.	Tutor asks questions challenging student thinking	Synchronous desk crit on student design work exhibited in personal or group space Asynchronous crit based on tutor annotations and corrections	<u>Tools:</u> VW conferencing and annotation tools <u>Workplaces:</u> personal workplace, group workplace
Design review and user evaluation Tutor's and other students' review of the designed artifact or system; User-centered evaluation of the designed artifact or system	Design review; heuristic evaluation; cognitive walkthrough; usability inspection methods; pluralistic walkthrough; user testing of interactive prototypes	Exploration of the prototypes and deliverables prior to their final presentation Formal presentations of the design proposal Open discussion and questions about the design Avatar-based remote user evaluation	<u>Tools:</u> Presentation and annotation tools; Video, audio and chat recording, simulation. <u>Workplaces:</u> Prototyping workplace; meeting room.

3.1 The design brief: researching, communicating and documenting the design problem in the Virtual World

The interaction design studio starts with the ‘design brief’: this is a written description of the project that is developed in concert between the client and the designer and its form and length can vary depending on the project scale (Ryd 2004). For interaction design learning, the design brief is initially a rather short presentation of an open-ended project or problem that neither can be addressed by a clear-cut approach or method, nor it has a unique ‘solution’. Depending on the educational approach, the design brief may have to be further developed by students themselves during design research, to identify and include fundamental guidelines and constraints that stem out of client wants and requirements. Typical methods for researching and communicating the design brief among tutors, students and clients include: interviews of the client and users, research on competitive products and related technology and feasibility assessment mainly with respect to budget and the design team ‘know-how’.

During the design brief activity, the VW may be used in a number of different ways. An initial action would be to post the design brief as a document in a virtual board and to attempt to identify and clarify the critical points and to organize the next actions using synchronous (e.g. in-world meetings) and asynchronous (e.g. comments and interpretations of the design brief) means. In addition, 3D models of buildings, machines and furniture can be built in the VW at the beginning of the project to illustrate the real world setting for which the design activity will occur, especially if these places are not easy to visit for design teams in the first place – e.g. for the design of an information kiosk or a large display to be placed in a public place like an airport or a stadium. Last but not least, synchronous conferencing functionality of VWs can be exploited to host initial meetings with clients. Certainly, these uses of VWs should be complementary to the physical meetings in which non-verbal and contextual cues (like (Dix et al. 2007): eye contact and gaze, gestures and body language, back channels, confirmation and interruption exclamations) help participants to frame their contribution and develop a wider understanding of their involvement. Therefore VWs can be useful at the design brief phase in order to help the design team keep track of the main issues, comments, questions about the main goals of the design; in some

circumstances VWs may also be employed for the building of 3D models about the physical place, where the designed artifacts and/or services will be introduced.

3.2 Design research in the Virtual World Design Studio

Design research refers to processes of information gathering, documentation and modeling about the domain, the client requirements, other related design artifacts and technology and the context of application. Despite the fact that interaction design is a relatively new discipline, there is a wealth of methods for design research that build and extend the corpus of related work mainly in the neighbouring fields of HCI (Human-Computer Interaction) and Product Design. Typical interaction design research methods include interviewing (and related strategies; Saffer 2007), observation (and related strategies; Saffer 2007), and contextual inquiry (Beyer and Hartzblatt 1997); while modeling methods about design research include, among others, personas (Brown 2007), work models (Beyer and Hartzblatt 1997), content inventory (Brown 2007), affinity diagrams, etc.

In general most interaction design research methods occur in the field. However, most methods also require some knowledge modeling to record research data and stimulate discussions for design (next phase of the work). In the VW, students can create 3D models that reflect their understanding during their design research, provided they are given interactive tools that can help them develop these models. For this modeling phase a number of (mostly) 2D design tools are used and therefore these can be integrated with a VW to allow discussions with design participants. The VW design studio can host digital work places where models about knowledge gained through design research are created by design teams for discussion and refinement, as well as for future reference. In the later phases, designers will need to have quick access to the large number of related resources collected and constructed during design research, and therefore, a virtual place can help them collaboratively organize the material, in similar ways like those at a physical design studio, e.g. a digital mood board posted at a wall of the virtual workplace, a flow chart drawn at an interactive white board, etc. Furthermore, this collection of project material in a single space may also offer tutors a deeper awareness of team progress and individual student contribution, and a chance to provide feedback when needed. All models are created in the VW,

they are stored in the VW database, and students can copy them to their personal inventory and organize them in folders for easier access at later stages.

3.3 Design thinking in the Virtual World Design Studio

Design thinking generally refers to the processes and methods about exploring the design space, investigating ideas about potential design artifacts and identifying and analyzing design options. Design thinking is characterized as the key ability of professional designers, who have developed “*at a high degree the skills of resolving ill-defined problems, adopting solution-focused cognitive strategies, employing abductive or oppositional thinking and using non-verbal modeling*” (Cross 1990). A number of methods facilitate designing thinking in interaction design including brainstorming (Cross 2000), scenario-based design (Rosson and Carroll 2001) and interpretation sessions (Beyer and Hertzblatt 1997). These methods are often applied in design studio sessions, where students discuss the findings from their design research to identify potential abstract solutions to the problem.

Design thinking methods may also take place within the VW with the obvious practical advantage of affording remote collaboration at a shared space. Furthermore, with the use of appropriate interactive tools, such as presentation devices, annotations, message and sketch boards, recording devices, etc., students may present their findings to the rest of the group by displaying images or whole presentations in the world, record discussion logs for later reflection, instantly sketch on shared boards to present their ideas and highlight some important conclusions of their discussions. The use of a single workplace in the VW for storing resources, executing activities and producing the results of these activities is valuable both for later use in the creative phases and for progress tracking and feedback. For example, a brain-storming session can be held in the VW following the steps proposed by (Cross 2000) as follows: (a) all members of the design team are presented with the goals of the design in terms of short statements formulated after design research; (b) each member writes down design ideas; (c) each member briefly presents their ideas with no critique allowed, while other members try to encompass elements to their ideas; (d) ideas are refined individually again; (e) second presentations of refined ideas are now processed by senior members of the team to a coherent set of ideas and design guidelines. The use of a VW can

add value to this process in several dimensions: digital workspace is unlimited in comparison to a physical studio space; avatars can explore and inspect models and sketches more easily (e.g. magnify, view from different angles) in comparison to paper sketching or a 2D display; asynchronous review of notes and models can also take place to allow for reflection and careful feedback.

3.4 Design practice in the Virtual World Design Studio

Design practice is often distinguished between conceptual design, i.e. expressing the fundamental ideas and requirements (Wang et al. 2002) and detailed design, i.e. the prototype or model with measurable specifications for construction and production. Various methods have been proposed in interaction design textbooks (Garrett 2003; Cooper et al. 2007; Brown 2007; Saffer 2007) for conceptual design including: personas, storyboards, mood boards, concept models, etc. Detailed design typically involves the construction of the form and function of the user interface through paper sketches to wireframes and screen designs as well as various prototyping methods based on media like paper, video the web.

In the traditional design studio, the typical tools for practicing design are the paper and pencil, which allow sketching and modeling for visually expressing ideas about form, function and structure. Sketching and modeling also invites others to provide comments and questions that can be easily altered or improved with paper and pencil or other cheap materials. In interaction design, paper prototyping strategies are also employed in a similar vein (Snyder 2003). The typical tools for modern detailed interaction design include: Web prototyping tools, CAD (Computer-Aided Design) programs and IDEs (Integrated (Software) Development Environments).

Conceptual Design is probably the activity that VWs have the most potential to support and improve (Koutsabasis et al. 2012). A realistic, digital place may be created in the world to represent the problem context, and avatar-based scenarios may be easily explored by the design team. These scenarios may also be recorded using machinima techniques to be further communicated. Students may import material that they prepared outside the VW, such as images and sketches of concepts, or they may collaboratively construct simple 3D forms of their proposed concepts. VWs such as Second Life and OpenSimulator include embedded tools for creating content. Users can construct complex objects by grouping and

transforming primitive shapes using a visual interface while being immersed in the VW. These tools are easy to use and do not require advanced 3D modeling skills and are, therefore, suitable for inexperienced students. The VW can be then used as a space in which students visually present their ideas in a design workplace, construct rough forms of solutions in realistically presented places and test various usage scenarios. This rich visual expression of the team's ideas and progress can be a subject of critique and argumentation by the team members themselves and also by tutors and fellow students, and this ability may lead to improved, refined concepts. Given that both the results of the design thinking processes and the conceptual designs are collocated in a single visual space, students can easily be asked to justify their design solutions based on the research outcomes, to present the paradigms they were based on, and to compare them with alternative choices. Thus, the use of a VW as a place of collecting rich data about the design problem and its possible solutions that can be argued upon, may also assist students towards following more systematic approaches for exploring the design space and communicating and justifying their solution.

Furthermore, an interactive product or system prototype that has been designed in detail can be presented inside the VW. Rich 3D graphics using advanced texturing and lighting techniques, such as environmental effects, bump maps, shaders and real-time shadows, can be used to improve the visual appearance of the designed artifact or place. E.g. one can create realistic landscapes, define the time of day, which affects the look and lighting of the environment, select and apply appropriate materials on objects, create custom effects using particle animation, define light sources that cast shadows, etc. Additionally, simulation techniques may be used to simulate part of a designed object's functionality. The extent to which detailed design processes may take place within the VW depends on the ability to easily build 3D models within it and to define their behavior. Given that students of interaction design studio courses do not necessarily have a programming background, the use of pre-constructed simulation objects as building blocks for the interactive behavior of their designed artifact would offer significant assistance. Finally, depending on the nature of the design, the solution may be presented in the VW at different scales. A real-scale (based on the avatar size) solution would be easier to include in avatar-based scenarios and to evaluate it, but in cases of small-sized products or

large places the use of larger or smaller scales would be more appropriate to have a good overview of the design solution.

3.5 The desk crit: tutor-student interaction in the Virtual World

The desk crit (Schon 1987) is the intense but loosely structured interaction between the tutor and the student at the time of student design work in the design studio. This interaction is crucial for students' learning since that they are confronted with explaining the rationale for their design decisions to the tutor, who is constantly challenging their thinking and practice. According to Schon (1987) the desk crit is central to the development of a student's ability to design thoughtfully. The desk crit is a powerful method of studio-based learning; however a number of challenges remain: the process of design criticism is stressful for learners and entails the danger of excessive subjectivity from tutors (Frederickson and Anderton 1990); students have to carefully keep track of comments, corrections and questions and follow up; the process may take too long and it is mentally demanding for the tutor when he has to oversee many students. According to Goldschmidt, et al. (2010) desk crits are "*sensitive and sometimes even charged settings, and teachers must exert much care to ensure their effectiveness as a learning opportunity for students*".

A VW desk crit session would require the tutor and the student to meet inside the VW design studio to discuss about student work. The student can exhibit the current state of his work in various models including sketches, personas, concept models, flow charts, 3D models, and so on, while the tutor can review these and pose questions and make comments in real time. Students can keep track of these questions and comments with interactive VW tools like note cards, annotations, chat recorders and so on. Some of these tools are already built-in in most VW environments, while others have to be developed and incorporated.

To address the challenges of the desk crit outlines above, the desk crit activity within a VW might also take place asynchronously, especially for reasons of necessity, when the available time does not allow for a thorough discussion between student and tutor. Tutors can review the progress and the deliverables of student groups by exploring their design workplaces and observing their posted documents, images and structures, to allow for a more careful feedback.

Compared to a desk crit activity in the classroom, tutors have more time to review

the outcomes and they are better aware of individual student effort. Their comments may be placed in a permanent and written form within the VW, so they can be later discussed and addressed by the design team. Tutors may also arrange meetings in the VW with student groups beyond classroom hours to assist, answer questions and review their work.

3.6 Design review and user evaluation in the Virtual World

Another characteristic of the design studio is the review or jury, which is a formal exposition of the design from the student's side to the tutor(s) and possibly other professionals outside the studio (Shaffer 2003). In interaction design, it is often that the (groups of) students can also provide critique on their team mates' work; for example in the prototype walkthrough (Hundhausen et al. 2010) a group of students presents their low fidelity prototype to the class having one of their members play the role of the user who thinks aloud and other students can interrupt at any time with questions and comments.

Furthermore, for interaction design it is important that users can test and evaluate the outcome of the design. Therefore, HCI evaluation methods can also be employed in interaction design, where end-users are considered the 'experts' who are to be engaged by the design team in the evaluation of the digital artifact according to various elements of measuring the user experience (e.g. Tullis and Albert 2008).

The design review can also take place in the VW through formal presentations of the design solution and questions and discussions about it. More important is the fact that tutors and students may explore the design models and prototypes prior to their final presentation and thus be able to post their comments and ask for further explanations of design choices. The advantage of using an integrated platform in this activity is that the learning community has the chance to see not only the final outcome, but also the resources and paradigms that led to it, provided that the students are indeed using the VW to share them. Therefore, they can better assess both the result itself and the proper use of the methods by the student teams.

Avatar-based user evaluation methods may be applied in the VW, provided that the design solution has been constructed in appropriate detail. Users may evaluate the aesthetics and affordances of the prototype by observing its 3D form

and exploring its structure within the VW, or they may evaluate its usability by testing its interactive behavior in predefined scenarios. In this case the realistic scale of the designed artifact may improve the quality of the evaluation, e.g. if the avatar can use a product in a way similar to its actual use, it might be easier to imagine oneself actually using it and thus to detect ergonomic or usability issues. Immersive virtual environments are already being used successfully for ergonomic and usability evaluation of new products (Bruno and Muzzupappa 2010), and a number of companies have transferred this process to Desktop VWs, such as Second Life: they present their designed products or services in VWs and let potential customers use them and provide feedback (Kohler et al. 2009). Finally, besides questionnaires and interviews, simple interactive tools such as ratings, positive/negative feedback and comments may also be used in the VW and be associated with specific aspects of the prototype to further assist the evaluation process.

4. A Virtual World Interaction Design Studio Course

Following the proposed approach described in the previous section, we have set up a VW, built the appropriate workplaces and tools, and used it to support a postgraduate Interaction Design Studio course that ran through a whole semester.

4.1. The Virtual World Platform

We have set up a VW server using the OpenSimulator platform. OpenSimulator is an open source platform for hosting VWs that includes most of the functionality of Second Life. We decided to use OpenSimulator instead of the more popular Second Life for the following reasons: (a) given that the platform was installed in our own servers, we had more freedom to configure the environment, control user access and store the user-generated content for future reference; (b) the majority of student activities required images to be uploaded to the VW (e.g. sketches, models, concepts, prototypes) and Second Life charges a price per image upload; (c) most of the features of Second Life are already supported by the OpenSimulator platform including the LSL scripting language that we used for development and d) OpenSimulator has extended LSL functionality with additional functions (OSSL functions), some of which were necessary for building

the supporting tools. More specifically, there are OSSL functions for dynamically drawing on 3D surfaces that were needed by sketching and messaging tools.

The OpenSimulator installation was enhanced with a MySQL database for storing the VW content and with a Freeswitch server for voice communication support. Students and tutors could log in to the VW using the Hippo Viewer or any other Second Life-compatible browser. The VW was installed in standalone mode – it was isolated from other regions to provide restricted access for students and tutors only.

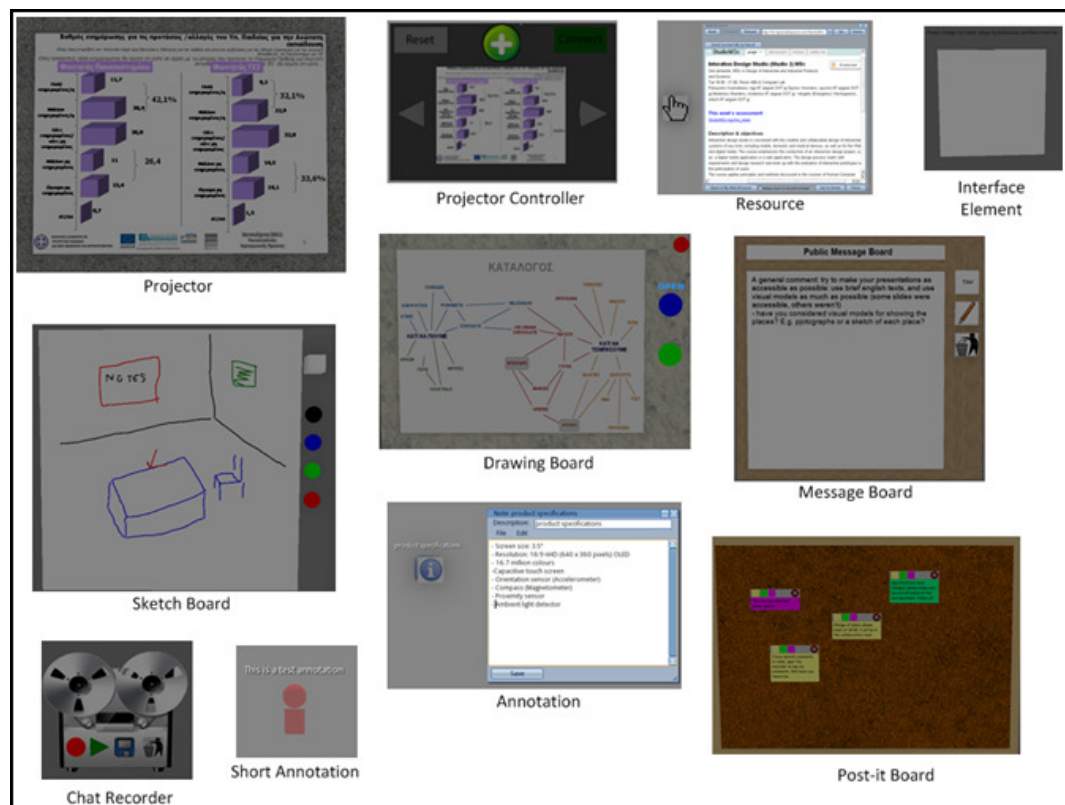


Fig. 1. The interactive tools of the VW design studio.

4.2 The virtual interaction design studio tools

We have developed a number of interactive tools (Figure 1) to support collaborative design activities in the VW. The tools have been designed on the basis of the identified student activities that could take place within the VW throughout the course (Table 1) and have been developed using the LSL/OSSL scripting language.

4.2.1 Presentations

We have built two tools for presentations, either in the whole class or within the same group, the *Projector* and the *Projector Controller*. Students are having their

own copy of the Projector Controller, through which they can upload and control their presentations. Any presentation can be imported to a Projector Controller as a sequence of images and is displayed on its own small screen. A student may then connect his/her own controller to the Projector and display the presentation to the rest of the group using the 'Next', 'Previous' and 'Reset' buttons of the controller. The Projector has also a 'laser pointer' feature for referring to the contents of the screen – if any user clicks on the screen a red dot appears on the point of reference.

4.2.2 Annotations

Annotations are essential objects for asynchronous collaboration. In our VW, they have been used for storing comments, questions, explanations, or simply for coordinating the design activities. Students were provided with the *Annotation* and *Short Annotation* objects and they could create multiple copies of them, define their contents and place them anywhere in the environment. Each Annotation object has a floating title and includes a notecard with the annotated text that can be read by simply clicking on it. The Short Annotation is a similar object that has only a floating text readable by anyone.

4.2.3 Collaborative Boards

Students were provided with four distinct tools that worked as boards for collaboration. The *Message Board* displays a text-only whiteboard, on which any student can add a new message. It has been used for storing ideas, facts or simply group meeting notes. The *Sketch Board* is a white surface on which users can draw sketches by simple mouse clicking and dragging. Students used it to quickly present new concepts to each other. To create more sophisticated and accurate drawings, they were equipped with the *Drawing Board*: a tool that displays Google Docs drawings in the VW and lets visitors immediately connect and edit the document. Finally, a *Post-it Board* object was also available for students to add text messages on it in the form of colored Post-it notes.

4.2.4 Recording

The *Chat Recorder* tool was provided to the students to record chat sessions, play them back, or save them as note cards. It has been used for storing group

discussion logs or for recording comments. However, due to restrictions of the LSL, it could not record voice communications; in that case students would have to use external recording software.

4.2.5 Resources

Students needed to store the resources related to their research in the VW and communicate them to others for later reference. Given that most resources are available on the Web (e.g. papers, web pages, images, etc), they were provided with the *Resource* object that displays a short description of the document it points to and opens the hyperlink in a new browser window when clicked.

4.2.6 User interface prototypes

We have designed and implemented the *Interface Element* tool for the implementation of the functional user interface prototype. Using multiple copies of this object, students can progressively construct windows containing elements such as buttons and images and define their behavior using simple commands. Each working element can have one or more of the following functions: a) operate as a Button that can send events to other elements (or itself) when clicked, b) operate as a Window, which can contain other elements and it can show or hide based on the event it receives, c) operate as an Image Container, which contains a number of images and it may display the next, previous or any indexed image based on the event it receives.

4.3 The virtual design studio workplaces

We constructed a number of in-world workplaces to support the interaction design studio activities. The workplaces are:

- *Classroom*: There was a single classroom in a central place in the VW to be utilized for class activities. This room was mainly used during the presentation sessions to let groups display their progress and explain their decisions to the rest of the class. It has been designed as a meeting space with a Projector on one wall and a large table with chairs around it for students and tutors. In the entrance there was a space for tutors' announcements, while any notes created by the tutors during class presentations were added as digital content in the classroom's boards.

- *Private rooms*: Each user had her own private room for which she had exclusive control of the entrance to allow for privacy. Students could insert and organise their own resources and freely develop their own concepts before presenting them to the rest of the group.
- *Group collaboration rooms*: There was one room for each group to be used for collaborative design and learning activities. It was equipped with appropriate interactive tools and furniture (tables, chairs, etc.), and groups were encouraged to design their space according to their own needs and planned activities. The role of these rooms were to support group meetings, to be used as places to collaboratively construct and present sketches and models, to store resources (web pages, papers, etc), to place comments and notes on the project's progress, etc.
- *Prototyping rooms*: One room was allocated to each group to be used for virtual prototyping. The room was initially empty and students were encouraged to construct a functional prototype of their designed artifact using the appropriate tools, and to place it in a realistic digital context. The prototype has then been evaluated by other users that interact with it as avatars.

4.4 Overview of the Course

The Interaction Design Studio course is offered at the second semester of the MSc program in Design of Interactive and Industrial Products and Systems, at the University of the Aegean, Greece. This is a transformation program that accepts candidates from a variety of disciplines related to design (e.g. computer science, engineering and architecture) and provides them with skills that enable them to make use of scientific and creative methods and technology, in order to contribute to the design of functional and usable products and services.

During the course, a Problem-Based Learning (PBL) approach (Wood 2003; Hmelo-Silver 2004) was followed in which students work in groups to deal with a problem that is related to practice and in which they are responsible for their own learning (self-directed learning) on the basis of their particular project, judgement and experience, while tutors act as facilitators of group work mainly in terms of asking questions to incite students' line of thought.

4.4.1 Design Brief

The design project given to students was to design a (multi-) touch interactive table or kiosk for a public place like a cafeteria/cinema/theatre, considering alternative installations and types of services, reaching to a functional prototype about form, ergonomics and user interface and interaction. Students had to work in groups and to make careful and justified use of design methods and evaluate the prototype with users.

The design brief was presented along with some other interesting projects and examples to stimulate students' ideas and interest. Students posted the design brief into their workplaces and asked questions to make sense of the project, identify the specific context of their application on the basis of their interests and reflecting on their skills and experience. Students kept notes (annotations) in the VW next to the design brief to keep track of the issues that had to be further pursued.

4.4.2 Design Research

The design project presented students with an authentic situation that had to be investigated in detail to make sense of the particular client and user requirements. Students had to make use of research methods like interviews, observation, data gathering and knowledge modeling about user requirements and the context of application.

Each student group followed a different approach to design research on the basis of what they deemed important for design. This was one of the primary targets of the pedagogical approach followed in this studio course: to stimulate students make a justified use of different methods, based on the problem faced and their judgment. For example, one team (information kiosk at a theatre) made use of contextual design models for representing requirements (Beyer and Hertzblatt 1997), while another team (multitouch cafeteria table) rest on interviews from potential users and started sketching alternate concepts of the table. To justify those approaches for design research, the first team reported that the stakeholders of the theatre wanted to put emphasis into ticket booking and selling through the kiosk – and thus an organizational view of the theatre was required and the contextual design approach was preferred. The second team found that the user experience of “hanging-out” in the cafeteria was the driving

design issue of their work, so they felt like experimenting for the very start with sketching and concepts of the user experience of interacting with a multitouch table.



Fig. 2. Design research documents arranged in the group workplace

The design research activities included both work in field and in the VW and lasted for a total of 3 weeks. The former included the conduction of interviews and observation, taking photos, and collecting related documentation (e.g. the menu of the cafeteria); the latter was about modelling, posting, documenting and commenting on this material in the group workplace (Figure 2). The process of making sense of the data and building related models occurred in physical meetings of student groups as well as in virtual meetings in the VW (Figure 3). The outcomes and models including personas, work models, and a list of guidelines and constraints were posted in the VW group workplaces, presented by the groups and commented by the tutors. We kept track of the discussions for future reference and corrections and areas of improvement were identified.



Fig. 3. Students present their findings in the VW

4.4.3 Design Thinking

The third activity that was taking place during the course time was (group) design thinking. Design thinking is an activity that happened in every session of the VW design studio and followed a number of different methods; this depended on the phase of design work and the particular requirements of the project. Thus, interpretation sessions were used by one team that followed the contextual design method to better understand user requirements and design guidelines; scenario based design was used by all teams to make sense of types of intended use of the object system by potential users (personas), that resulted to storyboards; brain storming was used to come up with ideas for user interface design. These methods were used by student groups alone during the week intervals and their results were documented in the VW (Figure 4).

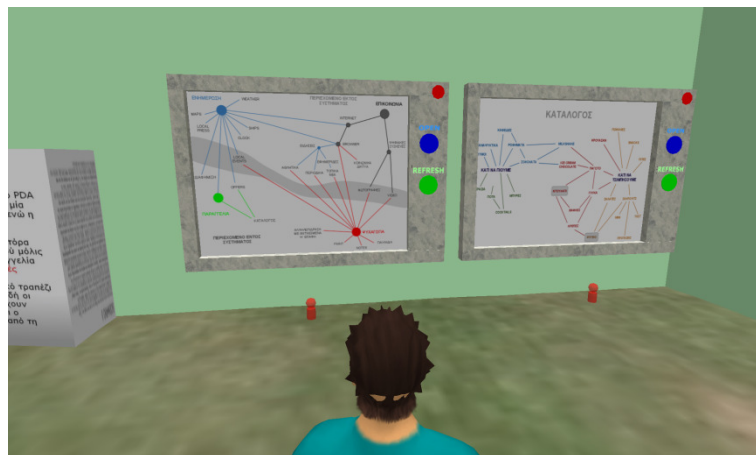


Fig. 4. Design thinking results posted in the VW

In addition, during the course sessions design thinking was modeled as a simple PBL tutorial process (Wood 2003), where students elect a chair and a ‘scribe’ to record the group outcome of the discussion and teachers facilitate the process with posing questions. The aim of this activity for each group was to complete a PBL whiteboard similar to that of Hmelo-Silver (2004) including the identification of facts, learning issues, ideas and action plan. The PBL session was held in the VW: students discussed and filled in the PBL whiteboard, while tutors posed questions to stimulate the process and to challenge students’ thinking. The action plan was posted in the VW to be consulted for the next course session.

4.4.4 Design Practice

Design practice occurred during the studio course sessions in which students developed various models about the form and function of the interactive system; this was carried on by students alone during the week interval.



Fig. 5. A model of the theatre used as a realistic context to place the kiosk prototype

Conceptual design was carried out with tools that included online 2D design tools for sketching of the basic layout and form of user interfaces as well as the construction of models like flow charts, concept models and storyboards. Detailed design was performed with online prototyping tools for the construction of wireframes and user interfaces. The VW offered interfaces with these online tools to allow students to work collaboratively if needed.

Furthermore, the use of interface element tool was used to develop a working prototype of the target system in the VW. The construction of working prototypes in the VW was optional for student teams. For example, one team opted to create a virtual prototype of the information kiosk for the theatre inside the VW (Figure 6). The other team opted for to conduct a paper prototyping session in the physical design studio since that they wanted to ultimately test their gesture-based interaction techniques for their multitouch table, and for which the specific implementation of the VW would not offer much support.

4.4.5 Desk Crit

The desk crit is both time and cognitively demanding for tutors, who have to pass from all students or teams (depending on the design task, design practice may occur in groups or atomically) and formulate the right questions and comments.

The VW design studio afforded the conduction of desk crit in both synchronous and asynchronous manner. During the course sessions tutors made oral discussions with students and groups, who recorded tutor questions and provided explanations. However, what was actually very helpful was the availability of student design work in the VW during the week interval. We kept visiting the VW to review student work during the week at a time of our convenience to provide feedback before the next course session.

4.4.6 Design Review and User Evaluation

The design review process concerned the intermediate design models that students developed throughout the lifetime of the course and of course subsequent versions of the interactive system. The design review occurred in open student group presentations in the VW, where tutors provided questions and comments on the designed artefacts focusing on challenging student options rather than providing workarounds and corrections. The latter was left to the students of other groups, who participated in the process by providing their opinions about potential solutions to problems posed by the tutors.



Fig. 6. User evaluation of the kiosk prototype: the user interface is presented both in realistic size (on the kiosk's screen) and in larger scale for easier comprehension.

Furthermore, the user evaluation of an interactive prototype was conducted in the VW, which concerned an information kiosk that provided services about theatre ticket reservations and audience reviews and recommendations (Fig. 6). Students set up a realistic digital environment of the kiosk, the theatre and implemented the user interface with the interface element tools of the VW. Then

they invited potential users (other students) to host a remote usability test in order to identify problems and to better inform their detailed design.

4.5 Assessment

The assessment of the design studio course is presented in terms of student progress and learning outcomes, and the perceived usability of the VW platform and tools.

4.5.1 Student progress and learning outcomes

The introduction of VWs in a design studio course was not easy to digest by students at first. This was due to their lack of experience in using VWs and their unfamiliarity to the pedagogical approach used. With respect to the former, at the start of the course we organized a tutorial to get students acquainted with the technology; this was a 2-hour session, in which students logged in the VW, designed their appearances, explored their digital workplaces and made use of the tools. With regard to the latter (PBL approach), we had to keep explaining the rationale of our facilitation in the first course sessions. A few students complained at first about the ‘lack of guidance’ and ‘lack of corrections’ on their work; however they got used to the approach especially after they saw their team mates to cope well. Thus, despite that in the first couple of weeks student progress was slow, students showed a steep learning curve after that time and responded positively throughout the process recognizing its novelty and the value of the approach.

Student work has produced various outcomes. Students made use of interaction design methods in a self-directed manner. The application of methods occurred both in the field and in the VW and most of the models produced were documented and exhibited in the VW thus allowing remote and asynchronous feedback by team mates and tutors. Students applied a number of methods and processes in the VW like PBL tutorials, presentation and critique, brainstorming, and usability evaluation. Additionally, students developed a digital prototype and conducted a remote usability evaluation in the VW.

4.5.2 Perceived Usability of the Virtual World Platform and Tools

For the evaluation of the VW environment, we first investigated the perceived usability of the VW tools with short questionnaires at the end of the course. Students were asked to rate their task performance (0:Bad; 10:Excellent) regarding the use of the VW for each one of the tools. Students' responses (Figure 7) indicate that they managed to make good use of most of the tools, especially the text chat, the projector and projector controller, the message board, the short annotation and the interface element. For other tools students did not meet particular problems, with the exception of the drawing board and the sketch board for different reasons. The usability of the Drawing board was not satisfactory because it required from students to configure its connection with Google Docs with a standard procedure each time they wanted to create a new drawing. The sketch board offered limited functionality to students: they had to use the mouse only to draw sketches with a single-style line, there were no accompanying templates or stencils for typical user interface objects like e.g. buttons and it supported only four colours.

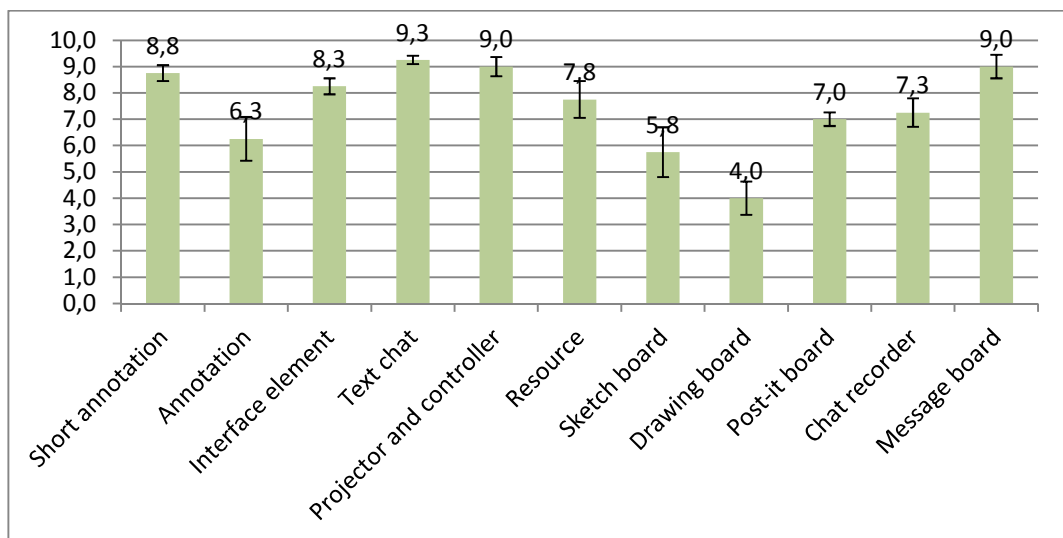


Fig. 7. Students' perceived usability of the VW tools (1: bad – 10: excellent).

Furthermore, we investigated students' perceived learning performance with respect to general skills and competencies of using the VW. We asked students to rate their performance with regard to a number of basic skills and competencies in the VW, like walking/flying, inspecting objects (magnifying/enlarging), managing objects in their inventory, managing access rights, etc. Students were asked to reflect on their performance at the first course and rate it, and at the last course (0:Bad; 10:Excellent). Figure 8 shows the average, self-reported performance of

students with respect to basic skills and competencies in the use of the VW. At the beginning of the course students felt they had moderate capabilities, however, they all progressed significantly with the skill development in the use of VW. This is a very encouraging result with respect to the usability of VWs for inexperienced users and supports their wider use for learning and teaching.

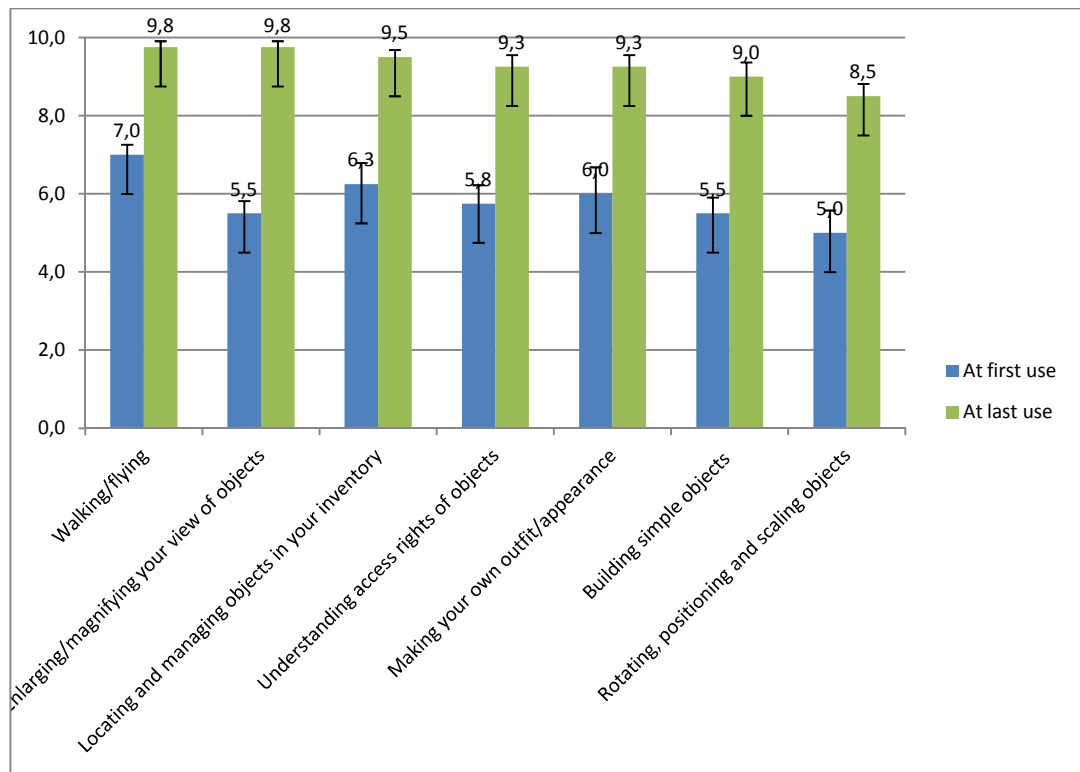


Fig. 8. Students' general skills and competencies of using the VW (self reporting)

Students were also asked to provide their views about whether VWs can effectively support collaborative learning and design. Their responses were positive of the potential but they identified the need for improvements of technology and tools: A student remarked: *“I believe that VWs can help the cooperation of design professionals and educators, but they have not reached to a point that everything can be designed inside them. For example it is not possible to design a multi-touch table so that avatars can apply hand gestures.”* Another student highlighted the VW communication affordances and pointed the usability issues: *“From the experience gained, I think that VWs can significantly support collaborative learning in design because of the rich group communication; you can design spaces and prototypes easily and others can see how design is progressing in real time and intervene; however it is important to understand the possibilities and not be disappointed by the low usability of some functions and tools”*. Naturally, some VW tools have not yet been developed at the sophisticated

level of their 2D counterparts, but on the other hand the collocation and integration of people, activities and tools in the same digital space, along with some empowerments that VWs can afford (e.g. flying, magnifying, creating and cloning objects, etc.) offer an engaging and inspiring design and learning experience overall.

5. Discussion and conclusions

In this paper we have explored the use of a VW platform and developed tools to support interaction design studio teaching and learning. We have presented an approach that identifies prospective VW workspaces and tools for typical phases of the design studio, and we followed this to the conduction of a blended postgraduate course that ran for a whole semester. The experience gained from this application is supportive of the argument that VWs can add value to a number of design studio activities. The VW platform and the developed tools had a positive impact on design and educational activities in a number of ways:

- Online meetings and presentations were conducted successfully because of the avatar representations, the voice and text chat capabilities and the effective use of the respective tools (projector and controller) by students. Related design activities that have been supported from online meetings and presentations are the design brief, the design research (especially about presenting/discussing the documentation), design thinking, and design review.
- The ability to collaboratively build within the VW allowed students to easily create knowledge models about their design project (e.g. personas, flow charts, concept models, etc.). These were particularly required at the design research and the conceptual design stages of project development.
- Students were provided with a tool (Interface Element) that allowed them to build simple 3D prototypes. The fact that VWs support 3D interactions through mouse clicks and can trigger custom object and avatar animations

dynamically, allowed for prototyping and remote user evaluation of some functional aspects of an interactive system.

- Another important positive aspect of the VW was its persistence that helped students and tutors follow up easily with the progress of the projects, and the affordances to collaboratively arrange objects in the environment that let students formulate their own working places, organize their resources and exhibit their work.

Considering the use of the tools, most of them have been extensively used by the student groups, despite some usability problems faced. Some of the tools have been used during all design phases: the projector and projector controller have been used during presentations and meetings and annotations have been regularly posted by students for keeping track of their progress and by tutors to send feedback and questions. The collaborative boards have been used during design research, design thinking and design practice phases to display ideas, plans, documents and diagrams. The drawing board allowed for collaborative creation and editing of drawings and charts, but it scored low usability by students. The message board was most useful due to its simplicity to post text documents in the VW. The interface element was necessary during the design practice to define the interactive behavior of the prototype. Its usefulness could be improved, if it supported a wider range of interactions and behaviors.

Besides the identified benefits, a number of limitations were also identified:

- Some students had difficulties in collaboratively editing documents and drawings posted in the workplaces during design research and design thinking activities due to limitations of the platform and the tools.
- Voice sessions could not be recorded from within the VW, so they had to use text chat or external recording software if they wanted to record their discussions.
- The prototypes proved difficult and time-consuming for most students to construct and their interactivity was limited to point-and-click actions.
- It was difficult to interact with the prototype in physical size and students had to build a larger size copy of the touch screen interface.

- Avatar-based evaluation is suffering from known issues in remote usability evaluation, like for example the inability to observe user reactions (Castillo et al. 1998).

Some of these limitations were addressed during the course lifetime, while some others have now been resolved for future use. For example, the difficulty to create complex 3D models and the time and effort it takes to generate new content was partially tackled with the use of pre-constructed content and with building blocks (like the interface element we used in our course) that can be easily combined to construct complex interactive systems. Also, the OpenSimulator platform currently allows a live webpage to be placed on a surface, so student groups can include web-based collaborative tools in their workplaces.

The use of a VW for teaching interaction design studio had several implications on the tutors' work as well. First of all, the fact that we could be aware of student progress and that we could inspect and comment on their work prior to the official presentation in class helped us to be better prepared and to intervene when appropriate. We believe that this awareness had a positive impact on the final outcome. However, we had to provide technical support very often to assist students in using the platform and its tools. It also took a significant amount of time to construct the initial workplaces, to manage user accounts and groups, and to properly arrange and organize the content. Therefore, the need for additional personnel is certainly one of the challenges of using VWs in education.

Nevertheless, if a significant number of courses are including learning activities in the VW, the extra cost for technical support per single course is expected to be reduced.

The experience out of this course is certainly supportive of the use of VW interaction design studios. However, more work is required to various dimensions to address a number of more general challenges. These include: (a) Refinement of the instructional approaches of VW design studios in order to encompass the particular characteristics of design studio constructivist pedagogies with the unique integrated set of VW affordances. (b) Other mid- and long-term applications of VW design studios in more courses, and possibly other design disciplines. (c) Further adaptation and application of interaction design methods in VW design studios, with the introduction of additional tools and processes; (d) Improvements in usability and platform maturity; despite that we have seen that

inexperienced users can make use of the tools, several problems may arise and further work in this direction is certainly required. (e) Integration of VWs with other tools of professional design, like Web prototyping tools, CAD software, image editing tools, 2D design tools, etc.; this integration would critically improve the usefulness of VWs for design studio learning.

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